Industry 4.0 Implementation in Indian MSMEs: A Social Perspective

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Abstract The current status of MSMEs in India suggests that medium-sized businesses have more advanced technology compared to their smaller counterparts. Small and medium-sized enterprises (SMEs) cautiously prefer to take baby steps when investing in emerging technologies. Many SMEs are financially constrained and reluctant to implement the digital technologies of Industry 4.0. The organizations need to showcase return on investment before implementing Industry 4.0 technologies. The effect of Industry 4.0 technology on society is a topic of growing interest among researchers. This study aimed to examine these effects using the triple bottom line approach to sustainable development. A model focused on sustainability is offered to assess the impact of Industry 4.0 technology on social sustainability indicators. This study also extends the technical approach that dominates academic literature on Industry 4.0 by identifying the benefits and challenges of its implementation process, assessing the importance of sustainability in Industry 4.0, and analyzing its potential social impact in a developing country like India. This paper considers how sustainable manufacturing research contributes to Industry 4.0 by summarizing present research efforts, highlighting relevant research issues, and evaluating research gaps and future development opportunities.

Keywords Industry 4.0 · Smart manufacturing · Sustainable manufacturing · Social sustainability

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1 Introduction

Lean and green manufacturing has been used and researched for two to three decades, yet sustainability concerns remain. Industry 4.0 could be a tipping point that leads to sustainable growth. This requires defect detection and remedy creation. Triple bottom line (TBL) covers the sustainable use of nonrenewable resources. Sustainable manufacturing requires the integration of goods, processes, and systems due to interdependent sustainability consequences. Every SME tried to survive the epidemic. Every company must adopt new tools and sustainable practices to flourish. The suggested research explores and analyzes the elements affecting Indian MSMEs' long-term viability. Two-tiered bibliometric and content analysis will be used to identify the conceptual framework of sustainable manufacturing literature (SM). This project will explore and deploy Industry 4.0 technologies for sustainable manufacturing. This essay examines the critical success factors for Industry 4.0 in Indian SMEs.

2 Literature Review

Organizations suffer sustainability difficulties if they fail to combine environmental, social, and financial benefits in their business plans [1]. Unbalanced social, environmental, and economic rewards prevent organizations from adopting a sustainable approach [2]. In addition, consumers' concern about the social and ecological impacts of industrial facilities has emerged as further pressure on manufacturers to change the current industrial growth model [3]. Organizations need a strategy to develop sustainable projects; an improper SM strategy won't inspire companies to invest in sustainable projects [4].

Information and automation technologies are combined during industrial transformation to produce new capabilities [5, 5]. Societies are affected by population expansion, resource depletion, land scarcity, environmental degradation, increased food consumption, and waste management. New production and consumption methods are fostered to preserve economic viability over the long term. Due to the challenges, research must be conducted into sustainable practices, standards, assessment systems, and new technologies. Industry 4.0 includes complementary technologies. Assessing the social performance of organizations has to be made the priority [7]. Industry 4.0 facilitates the long-term viability of businesses. Future-oriented, multidimensional procedures [8] will always try to boost sustainability in all perspectives. Rapidly implementing cutting-edge manufacturing processes and technologies to transform, record, distribute, and analyze data from production equipment and other autonomous systems. Companies get a competitive advantage by effectively manufacturing high-quality goods at lower costs and utilizing nonrenewable resources. Modern industrial technology can be integrated into production processes to interact and adapt in real time, enabling businesses to make intelligent goods and services [9].

2.1 Industry 4.0 and Sustainability

Industry 4.0 is an industry transformation that integrates information technologies and automation to improve performance. Financial, social, and environmental performances are examined. Industry 4.0 helps businesses achieve sustainability [10] It is feasible to boost return on investment by 15–20% by introducing BDA technologies [11]. In most businesses, including customer relationship management (CRM) data into analytics is seen as a viable strategy for increasing customer engagement and satisfaction [12]. Moreover, a comprehensive study of data from equipment and processes can increase the productivity and competitiveness of businesses [13]. Few of the Industry 4.0 tools have been discussed here. Table 1 shows list of the factors considered for performance measurement, the literature support from the select research articles, and their ranks based on the number of times the same factor has been used in the research in the context of social sustainability.

A CPS links physical devices and software to share information in various ways [12–14]. A CPS includes cybernetics, mechanical engineering, mechatronics, design, process science, manufacturing systems, and computer science. Embedded systems coordinate and couple physical products with their computational elements or services [6]. A CPS-enabled system uses physical input and output and cyber-twined services, such as control algorithms and computational capacities, to plan and build networked interactions. A CPS relies on many sensors. CPS uses touch displays, light sensors, and gyroscopes for numerous applications.

The IoT is an interconnected world where things are implanted with electronic sensors, actuators, or other digital devices to collect and communicate data [25]. IoT enables object-to-object communication and data sharing by connecting physical things, systems, and services. IoT can automate lighting, heating, machining, robotic vacuums, and remote monitoring. Auto-ID technology can be utilized to develop smart objects in IoT.

Internet and IoT make data more accessible and omnipresent, leading to big data [15]. Big data sources include sensors, devices, video/audio, networks, log files, transactional applications, the Web, and social media feeds. Manufacturing has a "big data environment." IoT (e.g., smart sensors) has accelerated data collecting, but it is unclear if this data can be effectively handled [16]. Traditional data analytics may not work with huge data [17]. Advanced analytics help firms and manufacturers with a lot of operational and shop-floor data find hidden patterns, unsuspected linkages, market trends, consumer preferences, and other relevant business information. Four I4.0 tools have been used to construct a hypothesis based on how often they have been used by researchers.

Kitsis and Chen [26] researched a number of different facets of sustainability and dove deeper into the social issues related to manufacturing to gain a better understanding of the SM domain. Ghobakhloo and Fathi [27] Due to the digital revolution, organizations can enhance productivity by using cutting-edge technology. Industry 4.0 gives firms a competitive advantage by allowing them to produce high-quality goods at cheaper costs and efficiently use nonrenewable resources. Kulatunga

Table 1 Industry 4.0 tools and the respective support from the literature survey

Industry 4.0 tools/Support	[18]	[15]	[16]	[17]	[18]	[19]	[20]	[21]	[22]	[23]	[23]	[10]	[24]	**Rank**
Additive manufacturing	*		*		*	*	*			*	*	*	*	5
Artificial intelligence	*		*	*	*	*	*			*	*	*		6
Autonomous and collaborative robots	*		*		*		*	*	*	*	*	*	*	2
Big data analytics	*	*	*	*		*	*	*	*	*	*	*	*	1
Cloud computing and manufacturing	*		*		*		*	*	*	*	*	*	*	3
Cyber-physical systems			*	*	*	*	*	*	*	*	*	*		4
Cybersecurity	*	*			*		*	*	*		*	*	*	7
Industrial internet	*	*	*		*	*	*		*		*	*		8
Internet of Things	*		*	*	*		*	*	*	*		*		9
Mobile systems and devices	*	*	*			*	*	*	*		*			11
Simulation	*	*	*	*		*	*	*		*		*		10

et al. and Huang [35, 36] The authors investigated small and medium-sized firms' environmental management systems (SMEs).

2.2 Performance Measurement and Its Indicators

A study from [28] shows that there are more than 40 indices and rating systems for sustainability assessment. Even though the topic of sustainability and Industry 4.0 plays an increasingly important role in the scientific discourse. Several metrics were used to evaluate lean manufacturing by Kumar et al. [29] better to understand the process's various stages and features. Organizations reaped the benefits of maintenance-related performance assessments, such as condition-based and reliability–contradance. Miragliotta et al. [30] The authors found that manufacturing businesses favor financial measures above non-financial metrics after classifying 73 indicators into twelve performance domains. Big data-driven supply chain research by Kamble et al. [8] has led to the development of new measures for evaluating manufacturing systems such as predictive quality and real-time defect identification and machine failure forecasting. Sustainability and Industry 4.0 are important organizational elements for sustainable production [7]. Many industrial enterprises lost money because they misunderstood sustainability India has a lower sustainability adoption rate than the U.S and China. The latest business technology includes BDA, blockchain, IoT, AM, and machine learning; if used in manufacturing, these can surely affect positively. Karimi and Walter [31] through case studies, the researchers investigated the use of emerging technology in industries. Industry 4.0 technologies provide significant contributions to social and organizational long-term sustainability. Mathiyazhagan et al. [32] according to the authors, sustainable technologies help minimize energy consumption and waste, increase energy savings, and encourage reuse and recycling. From a social sustainability standpoint, digital and intelligent technologies preserve employees' health and safety by removing monotonous and repetitive activities, encouraging individuals, and increasing job satisfaction. These discussed social sustainability indicators will help achieve greater heights in the manufacturing performance in terms of higher productivity, higher job satisfaction, and occupational health and safety of employees in the context of I4.0 implementation. Table 3 shows some of the factors considered for performance measurement, the literature support from the select research articles, been used in the research in the context of social sustainability and their respective ranking (Table 2).

Based on literature, the following research questions are framed.

- What is the status of social sustainability in the context of I4.0
- What are the I4.0 tools which affects social sustainability?
- What are the social implications of I4.0

Table 2 Manufacturing indicators and the respective support from the literature survey in the context of social sustainability

Manufacturing Performances/Support	[33]	[34]	[35]	[36]	[37]	[38]	[39]	[40]	[41]	[42]	[7]	**Rank**
Pollutant and effluent emission		*	*	*			*	*	*		*	2
Higher productivity	*		*	*	*	*		*		*		1
Smart working	*	*	*		*			*	*	*		1
Higher job satisfaction		*		*	*	*		*		*	*	2
Collaboration between companies	*		*	*	*	*	*	*			*	2
Collaboration between governments		*				*	*	*	*	*		2
Occupational health and safety	*	*		*	*	*	*			*	*	1
Human resources and rights		*	*	*	*		*		*			3
Job creation	*	*	*						*		*	4
Community and regulatory compliance		*		*		*	*	*		*		3

3 Research Methodology and Study Hypotheses

Based on the literature survey, the following hypotheses are proposed (Fig. 1).

H1a: The Industry 4.0 tool BDA has a direct and significant influence on manufacturing performance (i) Higher productivity (ii) Higher job satisfaction (iii) Occupational health and safety in Indian MSMEs. **H1b**: The Industry 4.0 tool cloud computing and manufacturing (CC & M) has a direct and significant influence on manufacturing performance (i) Higher productivity (ii) Higher job satisfaction (iii) Occupational health and safety in Indian MSMEs. **H1c**: The Industry 4.0 tool cyber-physical systems (CPSs) have a direct and significant influence on manufacturing performance (i) Higher productivity (ii) Higher job satisfaction (iii) Occupational health and safety in Indian MSMEs. **H1d**: The Industry 4.0 tool additive manufacturing AM has a direct, positive, and significant influence on the social sustainability of Indian MSMEs.

H2a: The contribution to society mediates relation between the BDA and manufacturing performance (i) Higher productivity (ii) Higher job satisfaction (iii) Occupational health and safety in Indian MSMEs. **H2b**: The contribution to society mediates the relation between the cyber-physical systems (CPSs) and manufacturing performance (i) Higher productivity (ii) Higher job satisfaction (iii) Occupational health and safety in Indian MSMEs. **H2c**: The contribution to society mediates the relation between cloud computing and manufacturing (CC&M) and manufacturing performance (i) Higher productivity (ii) Higher job satisfaction (iii) Occupational health and safety in Indian MSMEs. **H2d**: The contribution to society mediates the relation between the IoT and manufacturing performance (i) Higher productivity (ii) Higher job satisfaction (iii) Occupational health and safety in Indian MSMEs. **H2e**: The contribution to society mediates the relation between the AM and manufacturing performance (i) Higher productivity (ii) Higher job satisfaction (iii) Occupational health and safety in Indian MSMEs.

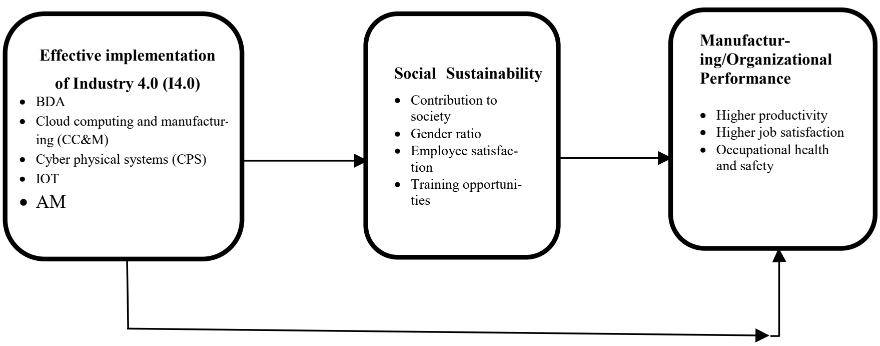

Fig. 1 Research framework

H3a: The gender ratio mediates the relation between the BDA and manufacturing performance (i) Higher productivity (ii) Higher job satisfaction (iii) Occupational health and safety in Indian MSMEs. **H3b**: The gender ratio mediates the relation between the cyber-physical systems (CPS) and manufacturing performance (i) Higher productivity (ii) Higher job satisfaction (iii) Occupational health and safety in Indian MSMEs. **H3c**: The gender ratio mediates the relation between cloud computing and manufacturing (CC & M) and manufacturing performance (i) Higher productivity (ii) Higher job satisfaction (iii) Occupational health and safety in Indian MSMEs. **H3d**: The gender ratio mediates the relation between the IoT and manufacturing performance (i) Higher productivity (ii) Higher job satisfaction (iii) Occupational health and safety in Indian MSMEs. **H3e**: The gender ratio mediates relation between the AM and manufacturing performance (i) Higher productivity (ii) Higher job satisfaction (iii) Occupational health and safety in Indian MSMEs.

H4a: Employee satisfaction mediates the relation between the BDA and manufacturing performance (i) Higher productivity (ii) Higher job satisfaction (iii) Occupational health and safety in Indian MSMEs. **H4b**: Employee satisfaction mediates the relation between the cyber-physical systems (CPS) and manufacturing performance (i) Higher productivity (ii) Higher job satisfaction (iii) Occupational health and safety in Indian MSMEs. **H4c**: Employee satisfaction mediates the relation between cloud computing and manufacturing (CC&M) and manufacturing performance (i) Higher productivity (ii) Higher job satisfaction (iii) Occupational health and safety in Indian MSMEs. **H4d**: Employee satisfaction mediates the relation between the IoT and manufacturing performance (i) Higher productivity (ii) Higher job satisfaction (iii) Occupational health and safety in Indian MSMEs. **H4e**: Employee satisfaction mediates the relation between the AM and manufacturing performance (i) Higher productivity (ii) Higher job satisfaction (iii) Occupational health and safety in Indian MSMEs.

H5a: The training opportunities mediate relation between the BDA and manufacturing performance (i) Higher productivity (ii) Higher job satisfaction (iii) Occupational health and safety in Indian MSMEs. **H5b**: The training opportunities mediate relation between the cyber-physical systems (CPS) and manufacturing performance (i) Higher productivity (ii) Higher job satisfaction (iii) Occupational health and safety in Indian MSMEs. **H5c**: The training opportunities mediate relation between the cloud computing and manufacturing (CC&M) and manufacturing performance (i) Higher productivity (ii) Higher job satisfaction (iii) Occupational health and safety in Indian MSMEs. **H5d**: The training opportunities mediate relation between the IoT and manufacturing performance (i) Higher productivity (ii) Higher job satisfaction (iii) Occupational health and safety in Indian MSMEs. **H5e**: The training opportunities mediate relation between the AM and manufacturing performance (i) Higher productivity (ii) Higher job satisfaction (iii) Occupational health and safety in Indian MSMEs.

4 Conclusion

This research demonstrates how modern technologies and ideas of sustainable manufacturing may help Industry 4.0 improve its sustainability in a social perspective. The evaluation of relevant literature also created a research agenda and growth projections. This research provides an overview of Industry 4.0 and Indian small and medium-sized enterprises. Both can support environmentally responsible manufacturing. The findings of this study contributed to the development of a research framework and scenario for the future evolution of the field toward normative Industry 4.0 adoption studies. All of the critical success factors that drive I4.0 rollout will guarantee TBL's long-term survival. To enhance the socioeconomic state of the country, local factors must be addressed. Industry 4.0 may benefit all sustainability criteria by applying sustainable manufacturing principles and current technologies, as demonstrated by this study, which enables companies to achieve all Industry 4.0 objectives. Humans at all levels of wealth and education must be made exponentially more aware of the sustainability dilemma. To develop and evaluate products and services in accordance with social sustainability criteria, inventiveness is required. These principles must be introduced to and comprehended by all participants, who are dispersed across the globe and have diverse cultural and educational backgrounds. Current research reveals a dearth of quantitative and methodological analyses of the social implications of Industry 4.0 and its potential contribution to sustainable development. Future studies should aim to bridge this knowledge gap.

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